

RESEARCH PRIORITIES FOR FY 2002

The Research Priorities presented here were reviewed and modified from the current FY2001 priorities in accordance with the Earthquake Hazards Program Five Year Science Plan (U.S.G.S. Open-File Report 98-143). This plan describes three major program elements that are the focus of the U. S. Geological Survey's Earthquake Hazards Program (USGS-ERP). These elements are: I. Products for Earthquake Loss Reduction; II. Research on Earthquake Occurrence and Effects; III. Earthquake Information (Seismic Networks). The ERP has identified the first two elements (I & II) as suitable for research supported through an external grants program. Each of these elements is cast in six regional or topical areas as listed below:

- Southern California (SC): From the Carrizo Plain south to the international border with Mexico
- Northern California (NC): From Cape Mendocino south to Parkfield, including the San Francisco Bay Area
- Pacific Northwest (PN): Washington, Oregon, and California north of Cape Mendocino (Cascadia) and Alaska
- Central United States (CU): The New Madrid seismic zone and surrounding areas
- National/International (NI): All earthquake-prone geographic areas not included in the above four regions
- Processes, Laboratory, and Theoretical (PT): Basic and applied research that has potential for reducing earthquake hazard in many geographic areas.

A peer panel of experts in each of these regional or topical areas reviews proposals under both elements. Proposals submitted in response to this solicitation must indicate the program elements and regional or topical area the proposed research addresses.

The USGS-EHP places high priority on investigations in four areas where large populations are exposed to significant seismic risk: Southern California, Northern California, the Pacific Northwest, and the Central United States. Studies in other, earthquake-prone regions of the United States should be directed to the National-International panel. Foreign research proposed must be applicable to domestic issues. Proposals for theoretical or laboratory work on earthquake processes should be directed to the PT panel.

All proposed work should indicate how the expected results can be applied to reducing losses from earthquakes in the US. This application of the proposed research should be clearly stated in a separate paragraph of the proposal, and this statement is a necessary condition for consideration of any proposal.

Pages 9-10 of this announcement describe the process of proposal evaluation by each of the above peer review panels.

Regional and topical coordinators may be able to assist applicants by describing related work within the USGS, identifying existing relevant data sets, and helping applicants establish contacts with USGS researchers working in similar areas. Coordinators are listed on the ERP internet page, <http://erp-web.er.usgs.gov>. Links to descriptions of USGS internal projects can be found on the same internet page by clicking on "Current Project".

As mentioned above, the EHP Five Year Science Plan describes the three major program elements that are the focus of the USGS-EHP; these elements were identified through USGS and independent external review. Two of these three elements are identified by the EHP as being applicable for research done through the external grants program and are described below. Following each element's description is a list of Priority Tasks for each geographical and topical area. We emphasize that this listing of Priority Tasks is not intended to discourage submission of proposals to accomplish other important tasks.

ELEMENT I. Products for Earthquake Loss Reduction

The USGS-EHP produces and demonstrates products that enable the public and private sectors to assess earthquake hazards and implement effective mitigation strategies. A key contribution of the USGS earthquake program is the series of national probabilistic seismic shaking hazard maps that are produced and updated periodically with new and refined information. These maps have grown out of the research efforts and systematically quantify the seismic shaking hazard for our nation. They are used as input for policy decisions on building codes and land use. In support of these maps, the USGS will produce accessible GIS databases of active earthquake source zones with up-to-date information on slip rates and recurrence intervals.

For urban areas at high risk from earthquakes, the USGS plans to produce maps and other products to quantify shaking amplification and susceptibility to liquefaction and landslides. The USGS is focussing on three of these urban areas that are at risk from earthquakes: The Seattle/Puget Sound Region; the San Francisco Bay Area; and the Memphis Tennessee region. For these three areas the USGS requires large-scale geologic and geotechnical mapping to better characterize and define the seismic ground shaking hazards at scales useful to engineers and planners. These products will be incorporated into the Federal Emergency Management Agency's (FEMA) loss reduction efforts. In response to requests from city planners, earthquake scenarios of large urban earthquakes will be developed for public planning.

Tasks that need to be addressed in each region are given below:

In Southern California

- Compile seismic, geotechnical and geologic data from both surface and from drill-hole observations necessary to predict regional ground motions and develop models to estimate variations in expected ground motions, accounting for bedrock excitation, nearby geologic structures, local topography, and soil-structure building interaction.
- Develop and verify methods for calculating time histories of strong ground motion, paying close attention to the quantification and propagation of both modeling and parametric uncertainties.
- Develop credible planning earthquake scenarios and produce synthetic time histories for scenario earthquakes in the Los Angeles and San Bernardino regions and for Los Angeles and San Bernardino regions.
- Collaborate with the USGS and university-based seismic networks to enhance tools needed for accurate and rapid portrayal of the severity and geographic distribution of strong ground shaking.
- Compile and provide access to geotechnical, structures, and seismic databases that will provide useful information for mitigation and emergency response efforts.
- Contribute to the development regional earthquake likelihood models (e.g., RELM, <http://pasadena.wr.usgs.gov/research/RELM>) in any of the following ways: develop workable models of the spatial and temporal distribution of earthquakes; quantify known and speculative faults in 3D space; contribute to a fault activity database of slip rates and other parameters; contribute to the historical earthquake catalog (e.g., quantify uncertainties of pre-instrumental events or provide focal mechanisms for instrumental events; update magnitude versus area (or length) regressions.
- Contribute to the development of attenuation relationships in any of the following ways: test median and uncertainty predictions of existing relationships with respect to recently obtained data or theoretical ground-motion predictions; develop new attenuation relationships using more recent data and incorporating new parameters to account for site effects, faulting style, directivity effects, or any other effects found to be significant;
- Contribute to the southern California 3D model in terms of refining velocity estimates, quantifying uncertainties, incorporating attenuation parameters (both scattering and intrinsic attenuation).

In Northern California

- Compile seismic, geotechnical and geologic data from both surface and from drill-hole observations necessary to predict regional ground motions and develop models to estimate variations in expected ground motions, accounting for bedrock excitation, nearby geologic structures, local topography, and soil-structure building interaction.
- Maintain and improve existing fault monitoring networks with downhole strain, geodetic, and creep measurements in northern California.
- The USGS is preparing large-scale seismic hazard assessments for the San Francisco Bay Area. Projects that will directly affect the quality and usefulness of such assessments are encouraged. In particular, studies are especially needed that:
 - map the geology on a 1:24,000 scale providing the basic input data for derivative liquefaction susceptibility and site-response maps,
 - Identify recently active faults and estimate their slip rates and potential segmentation for incorporation into a new and comprehensive Bay Area active fault map,
 - quantify relations to extrapolate shear velocities and attenuation from other types of sub-surface data,
 - Collaborate with the USGS, working groups, professional organizations, and regional consortia to develop products useful for local outreach and formation of partnerships with likely hazards map users.
- Compile and provide access to geotechnical databases that will provide useful data for developing mitigation techniques and planning emergency response efforts.
- Develop and verify methods for calculating both time histories and response spectral estimates of strong ground motion, quantifying both modeling and parametric uncertainties.
- Develop credible planning earthquake scenarios and map both the expected ground motion and produce synthetic time histories for scenarios earthquake cycles in the Bay Area
- Develop geotechnical information to model the location and amount of permanent ground deformation, including landslides, expected from Bay Area scenario earthquakes.
- Collaborate with the USGS and CISEN working groups to enhance tools needed for the rapid depiction of ground shaking.

In the Central United States

- The USGS is preparing seismic hazard maps for the Memphis metropolitan area. Projects that will directly affect the quality and usefulness of such maps are encouraged. In particular, studies are especially needed that:
 - collaborate with the USGS, working groups, professional organizations, and regional consortia to develop products useful for local outreach and formation of partnerships with likely hazard map users,
 - develop models of non-linear ground motions appropriate to Mississippi embayment sediments,
 - evaluate the effects of the Mississippi embayment structure (upper few km) on wave propagation (i.e., attenuation and the extent to which embayment structure acts as a wave-guide, reflects energy at its boundaries, etc.).
- Develop plans and implement the Advanced National Seismic System (ANSS) for the Central U.S. Region. In particular, develop tools needed for accurate, rapid portrayal of shaking (e.g., ShakeMap) appropriate to sparsely-recorded earthquakes.
- Develop credible planning earthquake scenarios for major Central U. S. urban areas.
- Collect direct measurements of the physical properties of deep sediments of the Mississippi embayment and actual ground motions themselves.
- Compile and provide access to regional databases that will provide useful data for developing hazard maps, mitigation, and planning emergency response efforts.
- Improve the seismic hazard models used in risk assessments, such as FEMA's program HAZUS.

In the Pacific Northwest

- Perform modern waveform analyses of historical intraslab (Benioff-zone) earthquakes in the Cascadia and Alaska subduction zones; inverting for the following source properties: CMT moment tensor;

source shapes, source directivity; radiated energies (E_0) and ratio of radiated seismic energy to scalar moment (E_0/M_0). Targeted Cascadia slab events include the large 1939, 1946, 1949, 1965, and possibly more recent events.

- Develop a 3-D model for in-slab (Benioff-zone) earthquake seismogenesis in Cascadia, incorporating the effects of slab kinematics, thermal structure, deformation state, mineralogy, seismic structure compared to seismic deformation.
- Contribute to the development of improved seismic attenuation relationships used in estimating strong ground motions for megathrust or in-slab (Benioff) earthquakes in the Pacific Northwest.
- Calculate strong ground motions in the Puget Sound metropolitan areas from subduction-zone, crustal, Benioff zone, and teleseismic earthquakes using 3-D models developed from SHIPS and other recent studies, and compare these calculations to observations (from SHIPS, site response studies, and the permanent network).
- Develop deformation models to explain the interaction (coupling) between the subducting Juan de Fuca plate and overriding North America plate in the Pacific Northwest.
- Collaborate with the USGS to enhance tools needed for the accurate, rapid, on-line portrayal of shaking in the Puget Sound, Oregon Urban Corridor, and Anchorage metropolitan areas.
- Contribute to seismic hazard maps in preparation by the USGS. An example of such contributions would include the development of methods using regional (Western Oregon, Washington, and British Columbia) crustal and deformation rates to estimate slip rates for large crustal fault systems in the Puget Lowland.
- Collaborate with the USGS, professional organizations, and regional consortia (e.g. Project Impact, CREW) to develop means to improve understanding of current earthquake hazards issues targeted to specific user groups within the Puget Lowland, the Oregon Urban Corridor, and Anchorage

In Other Regions of the United States and International

- Compile new and upgrade existing data that provide input information for seismic hazard maps. Examples of the types of data include: moment-magnitude-based earthquake catalogs from regional network data and historical information for earthquakes of magnitude 4 and greater in western North America and magnitude 3 and greater in central and eastern North America, information on the location and characteristics of active faults, and regional or local information on attenuation properties or ground-motion amplification that would impact hazard assessments.
- Develop improved regionally specific ground-motion attenuation relations in the central and eastern USA that include the effects of source finiteness.
- Determine recurrence intervals, slip rates, and segmentation characteristics and uncertainties of poorly studied active faults that directly affect the hazard in highly populated urban areas.
- Quantify crustal deformation at a regional to national scale. Develop methods to relate geodetic data to earthquake recurrence.

In Processes, Theoretical, and Laboratory Studies

- Develop methodology for modeling 3-D earthquake wave propagation in sedimentary basins. Test the methodology in well-characterized basins, with particular emphasis on the Santa Clara and San Bernardino basins in California.
- Develop applications of GIS technologies to large-scale earthquake hazard assessments.
- Develop methodologies for incorporating time-dependence into the quantification of probabilistic seismic hazard and loss.

ELEMENT II. Research on Earthquake Occurrence and Effects

The USGS pursues earthquake research to understand earthquake occurrence and effects for the purpose of developing and improving hazard assessment methods and loss reduction methodologies.

Because all of the current USGS products of the earthquake program have developed from its research efforts, the USGS will continue a major focus on understanding earthquake occurrence in space and time. The physical conditions for earthquake rupture initiation and growth need to be elucidated with field

measurements in fault zones and modeling of seismicity, crustal deformation, and other earth science data. Additional areas of interest include earthquake triggering, fault interactions, and the role of aseismic slip in relieving the buildup of crustal strain. Understanding in these areas will lead to better estimates of the long-term seismic hazards to our country. To address short-term seismic hazard evaluations, work on earthquake statistics and evaluations of stress fields associated with large earthquakes may facilitate estimates of likelihood and location of future earthquakes. Reducing future earthquake losses depends on an understanding of the damaging effects of earthquakes. Using data from our regional seismic networks, research in this area will address how complexities in the earthquake source, wave propagation effects, and near-surface geological deposits control the strong shaking. Studies will also investigate the factors that govern susceptibility to ground failure from landslides, liquefaction, and lateral spreading.

In Southern California

- Investigate Quaternary faulting, and develop regional models of active deformation and fault and earthquake interaction.
- Use waveform data to determine earthquake source parameters and crustal structure, and further develop and validate 2- and 3-D Earth models for Southern California..
- Develop and verify methods for calculating time histories of strong ground motion that investigate:
 - nonlinear sediment response and anelastic and scattering attenuation.
 - the degree of waveform complexity that comes from the source vs. propagation effects.
 - hanging versus foot-wall ground motion and directivity
 - the intrinsic variability of basin response with respect to different source locations.
 - the influence of 3D structural model refinements and uncertainties on ground-motion predictions.
 - the effects of the common approximation of truncating slow, shallow velocity units.
- Characterize the behavior of active faults segments and clarify differences between seismic and aseismic processes; evaluate seismogenic thicknesses and/or percentages of aseismic slip. The Los Angeles, Ventura, and San Bernardino basins are of particular interest.
- Utilize data from recent foreign earthquakes for the investigation of earthquake source, ground motions, and other issues relevant to hazards in southern California.
- Conduct geodetic and modeling studies, with particular emphasis on interpretation of SCIGN data and the SCEC Crustal Motion Map, especially in the Los Angeles metropolitan region and the eastern California shear zone.
- Develop methods for improved analysis and modeling of precise geodetic data such as SCIGN continuous GPS data, interferometric SAR data, and airborne laser swath mapping data.

In Northern California

- Determine paleoearthquake chronologies and refine slip-rate and recurrence estimates and evaluate segmentation models for major faults of the San Andreas system, in the following priority: Hayward, San Andreas, Calaveras, Concord-Green Valley, Rodgers Creek, Greenville, San Gregorio, Maacama, and West Napa faults.
- Characterize the behavior of active fault segments and clarify differences between seismic and aseismic segments; evaluate seismogenic thicknesses and/or percentages of aseismic slip.
- Use tomographic inversions of arrival data, analysis of surface wave data, and inversions of waveform data to test and define the 3-dimensional velocity structure of the crust.
- Characterize the extent, structure, geometry, and stratigraphy of basins in the San Francisco Bay region, with particular emphasis on the Santa Clara valley and Livermore basin.
- Determine the geometry, location, and rate of deformation on fold and thrust-fault structures in the San Francisco Bay Area and quantify the rates of compressional deformation associated with surface and blind thrust faults.
- Use SAR interferometry, GPS, and seismologic and geologic data to improve our understanding of fault creep and its effects on earthquake recurrence and magnitude for Bay Area faults.
- Utilize data from recent foreign earthquakes for the investigation of earthquake source, ground motions, and other issues relevant to earthquake hazards in northern California.

In the Central United States

- In support of ongoing seismic hazard mapping in the Memphis metropolitan area and other areas:
 - provide basic geotechnical data and develop and apply analysis techniques to infer ground motions (magnitudes) from paleoearthquakes,
 - locate and characterize seismogenic faults in the New Madrid seismic zone, particularly near Memphis,
 - develop testable methods of relating ground motions to intensity observations,
 - better constrain the southern and northern termini of the New Madrid fault zone and seismogenic potential of Reelfoot rift bounding faults,
- Develop models of intra-plate earthquake generation and design experiments to test them.
- Evaluate GPS monument stability and noise levels in unconsolidated sediments, like those of the Mississippi Valley region.
- Analyze all available geodetic data from the NMSZ.
- Conduct investigations to determine spatial and temporal characteristics of prehistoric earthquakes. Expand the regional coverage of such investigations beyond the area of current microseismicity in the northern Mississippi embayment to locate other possible source zones.

In the Pacific Northwest

- Conduct field investigations for evidence of ground shaking or displacement associated with the possibility of late Holocene earthquakes throughout the Puget Sound, in the greater Portland area, or in the greater Anchorage area
- Identify and characterize active tectonic structures in the Portland, Puget Sound, or Anchorage metropolitan areas.
- Conduct field investigations and develop models using existing observations necessary to understand crustal deformation in Cascadia. Proposed measurements in Cascadia must be integrated into a single regional crustal deformation analysis strategy.
- Develop models of predicted ground motions that include effects of long duration expected from plate-boundary earthquakes at Cascadia or in Alaska.
- Collaborate with the USGS in performing a seismic refraction/tomography investigation planned for late September/early October 2002 (Tacoma SHIPS). Tacoma SHIPS is designed to image upper crustal structure (basins and crustal faults) and the subducted slab geometry in the southern Puget Sound. Relate the slab geometry to slab seismicity.
- Develop and apply quantitative means for using ancient liquefaction to estimate strength of shaking at Cascadia or in Alaska.
- Improve the vertical resolution of geologic estimates of land level changes from Holocene earthquakes in Cascadia or in Alaska.
- Improve the dating of great Holocene earthquakes at Cascadia to investigate the coastwise extent of plate-boundary ruptures, particularly before A.D. 1700, and to clarify temporal patterns of great-earthquake recurrence.

In Other Regions of the United States and International

- Develop regionally specific ground-motion time histories and validate against observed ground-motion records. Devise methods of making these time histories available to the earthquake hazard community.
- Conduct Quaternary geologic, geomorphic, and paleoseismic investigations (including paleoliquefaction studies) and companion geophysical surveys to determine the spatial and temporal distribution of prehistoric earthquakes in earthquake-prone parts of the U.S. and U.S. Territories in the Caribbean region.
- Conduct paleoseismological investigations to estimate the times, locations, and magnitudes of large prehistoric earthquakes.
- Use inferred ground-motion from detailed damage data to determine which ground-motion parameters are correlated best with building performance in order to determine alternative parameters for the National Seismic Hazard maps.

In Processes, Theoretical, and Laboratory Studies

- Conduct laboratory and field studies of active and exhumed fault zones to gain knowledge of how stresses, fluid pressure, temperature, pore fluid chemistry, and internal fault zone structures and other physical factors and properties affect earthquake processes.
- Develop and test guidelines for interpreting fault stepovers, geometric irregularities and material property contrasts as delimiters of earthquake source zones in a range of tectonic environments.
- Implement conceptual and theoretical models of the earthquake process that can simulate both quasistatic and spontaneous seismic slip on major strike-slip or dip-slip faults at a regional scale. Test simulations using field and laboratory data and identify additional data that would constrain simulation parameters.
- Formulate and test hypotheses on the initiation, propagation, and arrest of seismic rupture and their implications for earthquake source effects on strong ground motion.
- Determine the physical mechanisms linking foreshocks to mainshocks, with long-term goals of more accurately calculating foreshock probabilities and developing public warning capability based on the identification of foreshocks.
- Improve estimates of long-term earthquake probabilities, especially by quantifying and determining physical reasons for the variability of recurrence times on identified, fault segment, and testing the hypothesis that repeated fault rupture is governed by identifiable segmentation.
- Determine the mechanisms by which significant earthquakes modify background seismicity in their immediate vicinities and trigger earthquakes at large distances, with the goal of issuing rapid public assessments of earthquake threat modification following major earthquakes.
- Test assumptions about earthquake recurrence used to construct the National Probabilistic Hazard Maps.
- Collect field data and conduct laboratory experiments to improve our fundamental understanding of the processes leading to liquefaction, lateral spreading, and slope failure during earthquakes.
- Analyze existing data to identify the parameters of ground motion that control damage to structures, and investigate soil structure interaction.
- Continue the focused fault-monitoring effort at Parkfield, California.
- Monitor deformation, fluid pressure, or electrical and magnetic fields to attempt recording of signals that could be earthquake precursors, and conduct field, laboratory, and theoretical investigations into the mechanisms of such precursors.
- Carry out investigations aimed at elucidating the relationships between faulted area, fault slip, and earthquake magnitude (including natural variability).
- Collect and interpret data documenting aseismic fault slip and deformation; compare quantitatively with geologic slip rates; identify locations with high slip rates, or with slip deficits relative to geologic rates.